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Points about Country Roads

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POINTS ABOUT COUNTRY ROADS.

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KNOXVILLE, TENNESSEE, U. S. A.

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INTRODUCTION.

Every farmer in the State is directly interested in the subject of country roads, and any points relative to their construction or improvement cannot fail to claim his attention. In some of our counties the roads are notoriously bad, and in many places the labor and cost of hauling the produce of the farms to market, even over comparatively short distances, are so great that the crops yield no profit, and land cultivation, beyond that necessary to raise simply what can be consumed on the farm, is neglected. Without good roads the farming interests of a community can make little or no progress. The farmer who is forced to convey his produce over bad roads cannot compete with him who has the advantage of good road facilities. The latter saves time, wear and tear of stock and wagons, and, what also ought to be considered, frequent loss of temper.

Just at this time, the subject of our roads and how we may best improve their condition, is receiving a good deal of public attention. Our people are awakening to the necessities of the case, and a call has been sent out for the meeting of a Road Congress at Nashville the 26th of this month (August). We believe it to be the duty of the Station to assist in forwarding this work as much as possible, and the present BULLETIN, prepared at the special request of the Director, by the Professor of Civil Engineering in the University, is published with that object in view.

F. LAMSON-SCRIBNER,

Director.

POINTS ABOUT COUNTRY ROADS.

BY WM. W. CARSON.

The price of a thing at the railroad station is fixed by the state of the markets of the world. The farmer gets the same for what he sells, and pays the same for what he buys, whether he lives one mile away or twenty. So the whole cost of hauling, and that in both directions, comes out of his pocket, and out of his alone. How much does this cost him? How much of it can be saved? How?

It is estimated that it costs a farmer more to haul a bushel of wheat than it does a railroad a ton; that our poor roads cost the farmer at least $15 a year for every horse, and that this loss amounts to more than $15,000,000 a year in Illinois; that good earth roads would save more than half the cost of hauling, and good permanent roads more than three-quarters of it, and that thorough drainage alone of the prairie roads would add $15 an acre to the value of the best farms in Central Illinois, (see Road Legislation for the American State, by Prof. Jenks).

For a country road, the question of most importance is the *draught:* that is the number of horses needed to draw a given load or (to state it otherwise) the load that one horse can draw. We need therefore to see what effect different grades and road coverings have on drought.

General Gilmore says (Roads, Streets, and Pavements, p. 23): "The following table, resulting from trials made with a dynamometer attached to a wagon moving at a slow pace upon a level, gives the force of traction in pounds upon several kinds of road-surfaces, in a fair condition; the weight of wagon and load being one ton of 2,240 pounds."

The General does not state who the "trials" were made by. They seem, however, to agree with the general average of results obtained by the best experimenters. And furnishing just what we want, in a convenient and uniform shape, we accept them and base this paper on them. But it must be observed that the condition called "fair" in the above would doubtless be called "first-class" in this Southern country. The means of Gen. Gilmore's figures are given below in the first column of Table 1. Starting from them, the writer has calculated the following tables.* As we start from figures which are in the widest sense general averages, so also, of necessity, are those in the tables. Observe also that they, like the data, apply only to a *slow pace* over a road in "fair" condition.

THE TABLES.

Table 1 gives, in the first column, as already stated, the mean number of pounds (as taken from Gen. Gilmore's book) required to draw a gross load of 2240 lbs. on a level. In the second column it shows the greatest rise of road per hundred (steepest grade) on which the vehicle will stand of itself.

The loads.—The tables, as will be seen, may be read so as to show the number of horses needed to do the work while making their usual effort. But of course the load must be known.

In tables 4, 6, and in the first two columns of 7, the load is that which one horse draws on a level earth road.

In tables 2, 5, and in the last two columns of 7, the load for each kind of road is that which one horse draws on a level road of that kind.

In table 3 the load for each grade is that which one horse draws up an earth road of that grade.

* The fact that a given condition may differ greatly from the mean, makes the figures in the second decimal places of the table wholly unreliable. They had to be inserted in some cases, however, to show that draughts on different roads or grades are generally different.

TABLES.

	Table 1 A		Table 2 B — The figures show, for each road, how many times the draught is as great as that on a level. They also show the number of horses needed to draw, without extra effort, the load that one horse draws on a level road of its kind.						Table 3 C — The figures show how many times the draught is as great as on an earth road of that grade. They also show the number of horses needed to draw, without extra effort, the load that one horse draws on an earth road of its grade.					
Rise per 100 .			0	3	6	9	12	15	0	3	6	9	12	15
Earth Road	200	8.9	1	1.3	1.7	2.0	2.3	2.7	1	1	1	1	1	1
Gravel Road	143½	6.4	1	1.5	1.9	2.4	2.9	3.3	.72	.79	.83	.86	.88	.90
MacAdam Road . .	65	2.9	1	2.0	3.1	4.1	5.1	6.1	.33	.49	.60	.67	.71	.74
Telford Road	46	2.0	1	2.5	3.9	5.4	6.8	8.2	.23	.43	.54	.62	.67	.71
Plank Road	41	1.8	1	2.6	4.3	5.9	7.5	9.1	.20	.40	.52	.61	.66	.70
Stone Trackway . .	12½	0.5	1	6.4	11.7	17.1	22.3	27.5	.06	.30	.44	.54	.60	.65

TABLE 4 C.

The figures show how many times the draught is as great as that on a level earth road. They also show the number of horses needed to draw, without extra effort, the load that one horse draws on a level earth road.

Rise per 100	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Earth Road	1.00	1.11	1.22	1.34	1.45	1.56	1.67	1.78	1.89	2.00	2.11	2.22	2.33	2.44	2.55	2.67
Gravel Road	0.72	0.83	0.94	1.05	1.17	1.28	1.39	1.50	1.61	1.72	1.83	1.94	2.05	2.16	2.28	2.39
McAdam Road	0.32	0.44	0.55	0.66	0.77	0.88	1.00	1.11	1.22	1.33	1.44	1.55	1.66	1.77	1.88	1.98
Telford Road	0.23	0.34	0.45	0.57	0.68	0.79	0.90	1.01	1.12	1.24	1.35	1.46	1.56	1.68	1.79	1.90
Good Plank Road	0.21	0.32	0.43	0.54	0.65	0.76	0.88	0.99	1.10	1.21	1.32	1.43	1.54	1.65	1.76	1.88
Stone Trackway	0.06	0.17	0.29	0.40	0.51	0.62	0.73	0.85	0.96	1.07	1.18	1.29	1.40	1.51	1.62	1.73

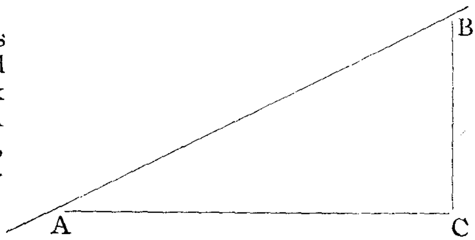
	Table 5 D. The figures show the number of horses needed to hold back, or whose work must be consumed by friction, in descending with a load which one horse draws on a level road of its kind.					Table 6 E. The figures show the number of horses needed to hold back, or whose work must be consumed by friction, in descending with a load which one horse draws on a level earth road.					Table 7 F. The load in the first two columns is that which one horse draws on a level earth road. That in the last two columns is for each road what one horse draws on a level road of its kind. The part of a horse's work consumed by the vehicle is somewhat less than the figures of the first and third columns. That consumed by the road is somewhat greater than the figures of the second and fourth columns.			
Fall per 100	3	6	9	12	15	3	6	9	12	15				
Earth Road	. .	. .	.01	.34	.67	. .	. .	.01	.34	.67	.06	.94	.06	.94
Gravel Road	. .	. .	.40	.87	1.33	. .	. .	.28	.62	.95	.06	.66	.08	.92
McAdam Road . . .	.03	1.07	2.09	3.11	4.12	.01	.34	.68	1.01	1.34	.06	.26	.18	.82
Telford Road	.46	1.91	3.37	4.81	6.23	.11	.44	.77	1.11	1.44	.06	.17	.26	.74
Plank Road	.64	2.28	3.90	5.51	7.10	.13	.46	.79	1.13	1.46	.06	.15	.29	.71
Stone Trackway . . .	4.37	9.75	15.07	20.36	25.60	.27	.60	.93	1.27	1.60	.06	.00	.96	.04

It is now necessary to say a few words about mechanics.

Everybody knows that it requires *work* to move or compress a thing (earth for example), or to hammer, or grind, or break a thing (rock for example). But it must be carefully observed that the tools used do no part of the work themselves. They simply apply the work already done. Now the work may be done at one time and stored in a body for future use, just as molasses may be put away in a barrel. We need to refer to two ways of doing this. Let a man break a rock by throwing an iron ball against it. All the work is done as soon as the ball leaves his hand. It is stored in the ball and so continues until transferred to the rock by the blow. The harder the man throws the harder will the ball strike. That is, the more work stored the faster will the ball travel. Let a horse hoist a weight. At any subsequent time let this weight be attached to a plow and by descending cause it to turn the soil, The whole work is done by the horse, and the weight simply holds it till needed. It is easily seen that the higher the weight the more work does it contain. As water may be stored in the form of ice and change, without loss, into the liquid form by melting, so work may be stored in a body in the form of height, and change, without loss, into the velocity form by falling. If, commencing at any time, water is used as fast as the ice melts, the amount of liquid water in the tank will remain the same. If it is used faster, additional water must be provided from an outside source; if slower, the liquid will continually increase. Now let a weight be hoisted. The whole work done on it is stored in the height form. As it falls this changes, without loss, into the velocity form, and may be may be made to crush or break a thing by striking. But fasten it to a plow or mill. If running this uses work as fast as that stored changes to the velocity form the weight will fall with uniform velocity. If it uses it faster, additional work must be furnished from an outside source or the weight will stop; if slower, the velocity will continually increase.

DISTRIBUTION OF THE WORK DONE BY THE HORSE.

When a horse draws a load over any road from A to B, the work he does, if he passes A and B at the same speed, is distributed in the following ways:



1. In overcoming the friction of the wagon itself, which is mainly between the wheels and axles.

2. In grinding the tires, and in doing so much of the breaking, grinding, and compressing of the material of the roadway as cannot be avoided by putting the road in "fair condition."

3. In doing so much additional breaking, grinding, pounding, compressing, and moving of the material of the roadway, and straining of the wagon, as may be due to a bad condition of the road, such as ruts, bumps, loose stones and clods, mud, &c.

4. In storing work, in the way of height, in the wagon and load. This is a definite quantity and can be calculated when the height C B and the weight are known.

These amounts would all increase with an increase of load. And the load that can be hauled is always limited by the fact that the sum of these four quantities must never exceed the work the horse should do while passing from A to B. And no way of hauling a heavier load can be devised but that of reducing one or more of these four quantities, or of damaging the horse by overwork.

THE AMOUNT OF WORK ABSORBED IN EACH WAY.

Let us try to get an idea as to what part of the horse's work each of these four heads consumes, and to see how much, and by what means, it may be reduced. We will commence with (3). It will be observed that the consumption of work under this head is due altogether to the neglected condition of the road. How much it amounts to cannot be expressed in figures. For the work of crushing one loose rock differs from that of crushing a dozen, and the blow struck by falling one inch into a rut from that by falling six. But whatever it amounts to, the fact is, the horse does it all. That it is generally a source of serious loss, even on roads that are called good, any one can easily convince himself. Let him do for a few feet, by the easiest method he can devise, what a wagon does in passing over a badly kept road. Let him make a rut in the mud or sand as broad and deep as the wagon makes; or let him crush, and rattle, and knock aside the stones, or pound or grind the road as the wagon does. It is well known that the draught on a bad road is considerably greater when the hind wheels do not track. This is due to the fact that the hind wheels, in not following the tracks cleared for them by the front wheels, have to do the extra work of clearing tracks for themselves just as the front wheels did. The work absorbed under head (3) will probably average, in the long run, not far from double the extra work that would be caused by failure of the wheels to track. The remedy is to make the road hard and smooth, and free from loose stones, so that the wagon shall pass without cutting or compressing it and without jolting. Work being thus saved the load may be increased.

Springs.—It may be remarked here that springs reduce the force of the blows struck by the wagon on the road. Thus a considerable quantity of the horse's work may be saved, especially on a rough road. As this work, if not so saved, is spent in damaging the road and wagon, but if so saved may be used in hauling a heavier load, the advantage of using springs is obvious.

Work Consumed by the Vehicle.—No direct experiments have been made, as far as the writer knows, to determine the amount of work consumed under head (1). By calculation, however, he finds that (with a vehicle similar, and in similar condition, to the one used in the experiments from which the data for the tables were obtained) the part of a horse's work consumed by the vehicle itself is certainly somewhat less (railroad experiments suggest about one-fourth less) than shown by the figures in the first and third columns of table 7—the load for the first column being such as one horse draws on a level earth road, and that for the third column such as he draws on a level road of the kind given. This consumption, for a given wagon, can only be reduced by proper greasing.

Work consumed by a road in "fair" condition.—Neither have direct experiments been made, as far as the writer knows, to determine the work consumed under head (2). He finds by calculation, however, that under the same circumstances as before, the part of a horse's work consumed in this way is certainly greater (probably by about one-fourth the amounts in columns (1) and (3)) than shown by the figures in columns (2) and (4) of table 7—the loads for these two columns being the same, respectively, as for columns (1) and (3). This work is spent in grinding, in breaking off and crushing particles of the material, and in compressing the road. This consumption of work is in the main unavoidable. It may however be reduced by putting the road in better condition generally, and by using vehicles with springs and very broad tires.

The Work Absorbed by the Grade.—The quantity of work absorbed (it is not consumed) under head 4 is the same for any road, and depends only on the load and the grade. Thus, from table 4, for a load which one horse draws on a level earth road each foot of rise per hundred absorbs .11 of a horse's work, and this no matter what the kind of road. Table 2, calculated for each 3 feet of rise per hundred, shows the number of horse's work absorbed by the grade for different loads. Thus, on a 6 foot grade, for example, .7 of a horse's work is absorbed by the grade if the load is one that a horse should draw on a level earth road; 2.9 of a horse's work if the load is one that a horse should draw over a level Telford road; and 10.7 horse's work, if the load is as great as a horse should draw over a level stone trackway. This shows that the grade exerts a far more damaging effect on the better class of roads than on the poorer. A practical recognition of this may be seen in the fact that grades of 1 foot to the hundred probably occur less often in our most perfect roads (railroads) than do grades of 15 in our most primitive (earth roads).

Extra Work by the Horse—In an emergency the horse must of course do extra work. How much extra work he can do has never yet been determined, as far as the writer knows. But it must largely depend on the horse himself and on the circumstances of the case. But it is not probable, especially as he works at disadvantage on a slope, that the average horse will be able steadily to ascend a hill of any length while making more than double the effort that should usually be required of him. On this assumption we may see from table 2, how a grade increases the cost of hauling. In this table, the load for each road is the full load that one horse should draw on that road when level. Since, in the emergency, one horse is to do the work of two, we see that he would go up a 9 foot grade on an earth road, a 6 foot grade on gravel, or a 3 foot grade on Macadam. Notice especially that the grade which a horse would thus ascend with a full load is practically that given in the second column of table 1. This coincidence is really exact and is due to our assumption that the horse is able in emergency to double his usual effort.

Extent to which grades increase cost of hauling.—On a macadam road a load which one horse would draw on a level would (table 2) require the ordinary work of about four horses to draw on a 9 foot grade. Now, if the horse can do but double work, it is evident that he can only draw the half of his usual load over such a grade, and hence he needs to make twice as many trips in order to do a given amount of hauling. The case is even worse than this, for these are gross loads. Hence the weight of the wagon must be subtracted from each half load (that is, twice as often) in order to find the net amount hauled. Thus a single 9 foot grade on a macadam road more than doubles the cost of hauling. In the same way it may be seen that a single such grade on a stone trackway makes the cost of hauling more than eight times as much as it would otherwise be.

The amount of work absorbed by the grade can only be reduced by reducing the grade itself.

Extent to which a Friend may be turned into an Enemy.—When the descending grade is steeper than that shown in the second column of table 1, a part of the horse's work must be spent in damaging something. It must be noticed that the work absorbed by the vehicle and roadway (heads 1, 2, and 3) is entirely consumed and lost, but that absorbed by the grade is simply stored in the wagon and load in the way of height. As the wagon descends the work so stored changes from the height form to the velocity form. In the descent the vehicle and roadway (heads 1 and 2) need to consume work *faster* than that stored changes from the height form to the velocity form if the grade is *less* than that in the second column of table 1 Hence in such cases the horse must do work enough to supply the deficiency. If the grade is just that shown in table 1, the work is consumed exactly as fast as it changes form, and the wagon rolls down of itself at a slow and uniform speed. On the other hand, if the grade is steeper than that in table 1, the wagon and road (heads 1 and 2) do not consume the work as fast as it changes form. In such cases the velocity increases until by extra jolting, pounding, hammering and breaking the stored work is consumed as fast as it changes form. Now this increase of speed is generally objectionable. But the work inevitably changes form in the descent, and no way has yet been devised of utilizing the excess. And worse still, since work, like matter, is indestructible, this excess cannot be destroyed but must be used, and *that to damage something*. It is used in damaging the horse by making him consume it by holding back with his neck (a severer operation than most men believe); or in grinding the tire and brake block away against each other; or in plowing and grinding the roadway with the wheel (by locking the latter). On steeper grades even this will not consume work fast enough, so the lock-chain is put under the wheel so as to plow a deeper trench, or, in the case of a street car, sand is thrown on the rail to grind the wheel the faster.

The amount of work that must be used in damage.—When the descending grade then is steeper than in table 1, a definite part of the work done by the horse must be turned against the road, or vehicle, or horse himself. In tables 5 and 6 may be seen how much this is for different roads and grades. In table 5, the load for each road is what one horse draws on a level road of its kind. In table 6 the load is the same throughout and is that which one horse draws on a level earth road. Thus (table 5) in descending a 12 foot grade on a Macadam road with a full load for such a road, the work of 3.11 horses must really be spent in damaging something. But in descending the same grade on an earth road, with a load suitable for an earth road, the work of only .34 horses need be spent in damage.

The maximum grade should be the same whether for ascent or descent.—We see then again how much more hurtful steep grades are to the better class of roads than to the poorer. We saw that a horse, with proper extra effort, can ascend with his ordinary load as steep a grade as that shown in the second column of table 1, but that on a steeper grade the load should be reduced. We have just seen too that in descending a grade no steeper than that of table 1, no work is lost, but that on a steeper grade a *certain part* of the work done by the horse must (often many times as much as he could do *while descending*) be spent in damaging something. Hence, whether as a matter of ascent or descent, we conclude that a grade as steep, for each kind of road, as that shown in table 1 may be used; but that a steeper grade should never, *under any circumstances whatsoever*, be allowed on a country road. In cities, weightier interests than those of hauling may sometimes demand their use.

GENERAL REMARKS.

Whether money should be spent on a road, and how much, depends on what returns it would make. Thus, considering pecuniary returns only, with money at 6 per cent, it would be bad policy to invest $1,000 where it would yield 5 per cent, but it would be good policy to invest $1,000, and better still to invest $100,000, where the yield would be 7 per cent. Now the per cent yielded is evidently twice as great if $1.00 does the work as it would be if $2.00 were consumed in doing it. So the advisability of spending money on a road depends in large measure on how judiciously the expenditure is to be made. And it is of this last that we have now to speak.

The expenditure will fall under the following heads:

1. Location, i. e., the accurate selection of the route.
2. Construction, including the cost of right of way.
3. Maintenance.

The first step towards having anything well done is to put it in the hands of a man who knows how to do it: of a surgeon, if it is a case of surgery; of a lawyer, if it is a legal question; of an engineer, if it is a matter of engineering. Experience and engineering skill of a high order are needed to fit a road exactly to the ground so as to make the cost of maintenance a minimum, to avoid unnecessary grading, and to decide for each section of it, in view of the locality and of the kind and amount of traffic it must bear, just what kind and thickness of road covering, and just what grades, are most judicious. These and many other things should be settled by carefnl study and comparisons after making an accurate survey and map of the ground, after calculating the cost of right of way, grading, masonry, bridges, &c.,

for different lines and grades, after getting the best information possible both as to cost and quality of the various materials available for road covering, and after as close an estimate as can be made of what the traffic is to be. Each of these should have its proper influence on the final decision. If allowed either more or less the cost of the mistake will finally be paid, in some way or other, by the community. Much the same can be said with reference to the maintenance and repairs of roads already built.

"Road commissioners under the present system say frankly that they think at least one-half of the money tax expended for roads in the State of Illinois is wasted through ignorance or carelessness, while of course a much greater proportion of the labor tax is wasted, not to speak of that which results in a real detriment to the road. This waste, then, which could be largely prevented by a supervising engineer, costs that State annually from two to two and one-half millions of dollars of the tax already collected, to say nothing of the loss arising from the poor roads."—(Prof. Jenks, p. 43.)

A COUNTY ENGINEER.

The first step should be to employ a competent county engineer of roads. And here we will remark that work, whether of brain or muscle, has its market price as well as wheat or corn, and is not to be had for less. An engineer, if competent to supervise a county's roads, will demand a good salary. A willingness to serve for less than $2,000, without satisfactory explanation, should be considered sufficient evidence of incapacity. Fitness should be the sole test of eligibility. Such things as his place of residence, his skill in organizing primaries, his views on the tariff, predestination, or infant baptism, should never be considered. When once appointed, he should be given full charge of all the county's roads and bridges, and no bills should be paid or contracts awarded until approved by him. His term of office should expire when his work shows bad results, and not before. Of this the appointing power should be the sole and final judge. This brings us to the most important question.

How should the appointment be made?—The appointment should be shielded from political influence with jealous care. If the State has an Engineer of Roads and Bridges the appointment should of course be made by him. If not, an appointment made by a board composed of the Chancellor and Circuit Judge might result as favorably as any.

A State Engineer of Roads and Bridges.—Every State should have such an engineer, and a man fully competent to fill the place can hardly be secured for less than $4,000 a year; one willing to work for less should never be appointed. The remarks just made about the appointment of a county engineer apply here with added force. The appointing board should, of course, have power to remove at pleasure. The State engineer should direct and supervise the work of the county engineers, and should require monthly reports of them. He should make full reports to the Governor once a year. He should have power to condemn and close any highway bridge in the State, whether in city or country, which he deemed unsafe. No contract for the erection of any bridge, whether in city or country, should be awarded, or money paid therefor, except as approved by him.

The writer is fully satisfied that the employment of these engineers, substantially as suggested, and the giving them adequate power to act, would, with no increase of the road tax whatever, result in giving the State a better system of roads than could be got by doubling, or even trebling, the tax uuder the present system. Moreover, the people stand ready to increase this tax whenever they see it judiciously applied. "That the people thoroughly understand the necessity for good roads, and willingly contribute of their money and labor to maintain them, the statements herewith published abundantly prove. That so little is accomplished is not for want of men and money, but because both money and labor are frittered away, for the want of systematic methods and such general oversight and competent direction as are necessary in all public as well as private enterprises." (Report, Feb. 1890, of Hon. B. M. Hord, Commissioner of Agriculture.)

THE LOCATION.

The material for the road covering should always be selected before the location of a road is commenced, and for this reason. The exact position of the road, and possibly the route itself, will often depend on the grade adopted for the maximum. Thus, with a grade of 15 feet to the hundred a road might go straight over a hill with little cutting, whereas, on the same line, with a grade of 1 foot to the hundred, the cutting might be heavy. To avoid this, if the easy grade were adopted, it would be necessary to go around the hill or to ascend it by an oblique or winding route. Now, it has already been shown that, for each kind of road, there is a grade (see the second column of table 1) which should never be exceeded. As already stated, a horse, by extra effort, can draw any load up such a grade that he should draw regularly on a level. And no unnecessary damage must be done the roadway in descending it. If a single steeper grade occurs the wagons must haul only part of a load. On the other hand, if an easier grade than this is adopted as the maximum, the grading will be needlessly heavy, or else, to avoid this, the road must be circuitous and longer, neither of which would allow an increase of load.

The maximum grade having been adopted, the engineer must decide in each case, and he alone can do it, whether it is most judicious to cut through a hill or wind around and over it. The first would require more grading and the part of the road in the cuts would be more expensive to maintain. The second would lengthen the road, thereby taking more land for right of way, necessitating the increased expense of building and maintaining the additional length of road; and, by obliging every vehicle to travel this additional length, would impose a perpetual tax on the community. It must be observed, however, that the windings of a road really add little to its length if its direction differs at every point very little from that of its objective point. So the road may be made, with slight increase of length, to deviate considerably from the straight line and thus to avoid a hill or to pass through a desired point.

UNDULATING ROADS.

When the grades in table 1 are not exceeded, the work done in hauling a given load a certain distance is just the same whether the grade is level or undulating. This is so because the extra work done in ascending is not consumed but only stored for use on the descent. But it must be carefully noticed that *fatigue* and work are very different things. The same amount of work done in different ways may cause much or little fatigue. The work of carrying a sack of shot a hundred yards is the same whether done on the shoulder or at arm's length in one hand. But how about the fatigue? So, also, though the work of carrying a hundred such sacks across the room is not great, the fatigue of doing it may be made so by carrying too many at one time. The point is, that over-exertion, or working in an unnatural way, causes any animal increased fatigue, and reduces his capacity to work. The popular idea, then, that a road should undulate, so as to rest the horse, seems altogether wrong. As a horse drawing a full load has to make extra effort in going up a grade, and that while in an unnatural position too, the writer is decidedly of the opinion that the most favorable grade possible between any two points would be one uniform and continuous slope. If the points happen to be on the same level, this would of course itself be an absolute level. While it is necessary to rise and fall in crossing hills so as to reduce grading, and to have a sufficient slope in cuts to secure drainage, these undulations should be regarded as a necessary evil, and should be avoided as far as circumstances admit. And this is the more desirable since the steeper the grade the more does the road wash in heavy rains. Hence special effort should be made to get every grade as light as possible.

ALIGNMENT.

The interest of the individual is second to that of the community. The road should never be carried through out of the way places or along section lines to avoid passing through a farm, as is often done to the great inconvenience of the community. The owner of the land is entitled to full compensation for any damage inflicted, and the cost of this damage should influence the location as much as the cost of so much grading, but no more.

CONSTRUCTION—GENERAL REMARKS.

Under the head of construction, we include alterations and repairs to an old road.

Everybody admits the wastefulness of buying from those who give short weights and measures. It is a notorious fact that those who pay their road tax in labor, seldom give a half a day's work for a full day's time. The other half of the day, spent in loitering on the road, is a clear loss to the community. The road tax then should be paid in money. In employing labor it would be proper to give the preference to those who pay the tax, provided, they like others, give a full day's labor for a full day's pay. But no short measures should be allowed. This, without hardship to any, would make the road tax twice as effective. But the best labor without a competent foreman works to poor advantage. The foreman should be chosen for his fitness, and should be paid. He should not be elected, but appointed, and that by the county engineer, when there is one.

WIDTH OF ROAD.

The right of way should be acquired during, or immediately after, the location. A sufficient width should be acquired then to answer any demands that may be made on the road in the future. But the roadway should be made no wider, at the time, than the travel actually needs. In the first place, as we shall see later, one of the first conditions for a good road is perfect drainage. Now the closer the side ditches are together the better the drainage. Next, a prolific source of damage to the road is the washing of heavy rains. It is easy to show that this washing varies with the square of the width. For example, other things being equal, a road twenty feet wide washes four times, and one

30 feet nine times, as fast as one 10 feet wide. Again, there is probably no country road in the State of Tennessee in first-class condition. It is economy then to spend all the money that can be put on a particular road in improving only so much of it as is actually needed. For a better condition means cheaper hauling and cheaper maintenance. In the writer's opinion no road in the State should have a greater clear width of roadway than 16 feet, for the present at least, except in the vicinity of cities or in some exceptional locality. It should, of course, have sufficient extra width on curves for the longest teams.

CONDITIONS FOR A GOOD ROAD.

We saw (table 7) that the main part (sometimes more than 94 per cent.) of a horse's work, even over a road in "fair" condition, is generally spent in changing the condition of the road itself. Now if any part of the work so spent can be saved, it can be devoted to drawing a heavier load. A saving may be made in two directions: (1.) By putting the road in such condition as to moisture as to prevent, as far as possible, its consumption of work. 2. By doing before hand (and in a cheaper way) as much as possible of the work that the horse would have to do on the road. Now remember that every impression or change made in the road, either by the wheels or the horse's hoofs, either in making tracks or in moving, turning, burying, or breaking stones, or in any other way whatever, represents a consumption of so much of the horse's work. It is a well known fact that the drier any earth is, except unconfined sand, the better does it resist change of shape or the moving of any object buried in it. Hence, to save in the first direction, all roads (except those with a surface of sand) should be drained in the most thorough manner, and the road covering should, as far as possible, prevent penetration of water from above. To save in the second: The compression of the earth, the bedding of the stones in it, the breaking, crushing, and consolidating of these stones into a smooth and solid covering should be done before hand, especially as this can be done in a cheaper and far better way than by the horse and wagon. If a wagon should go partly loaded, so as to use some of the horse's work in finishing the surface, ought not the road itself to be graded by requiring every passing vehicle to leave room for half a load of earth? The fact is, the horse and wagon can never consolidate the road into a smooth and satisfactory surface. The road-roller alone can do this, and it furnishes, moreover, the cheapest means of doing it. And steam is likewise the cheapest power to operate it with, especially since its engine may be used to run a stone crusher. Although its first cost is considerable, as is also that of operating it, it should always be provided. In sparsely settled regions two or three counties might own one jointly.

DRAINAGE AND SURFACE.

As damp sand moves or flows less easily than dry, a special effort should be made to preserve the moisture in a road whose surface is to be sand. To this end, there should be no side ditches; the roadway should, if possible, be a single track, with occasional wide places for passing; trees and vegetation of all kinds should be induced to grow as close as possible to the road, so as to prevent evaporation and to resist, with their roots and fallen leaves, the flow of sand from the wheels (Prof. Shaler, in Scribner's Magazine, for Oct. 1889).

But all other road surfaces should be kept, by being built on banks or by side ditches as close together as possible, at least two feet above water level. The earth should be rolled until thoroughly consolidated, and this whether there is to be a road covering of any kind or not; and the cross section should be brought to the shape of the finished road as shown below. This rolling would complete the earth road. If a Telford road is to be made the sub-pavement should now be laid and properly wedged with small stones and consolidated by rolling. Then a layer of broken stones should be evenly spread and consolidated by rolling. Then another layer may be added to complete the road, and likewise rolled. For the best class of road, however, another layer must be added and rolled. Broken stone consolidates best when wet.

If no roller can be had, the best that can be done is to throw the road open to travel during the construction of its surface. Thus one layer should not be added until the previous one has been consolidated as much as possible by the traffic, the ruts being repeatedly filled with the broken stone.

For a macadam road, substitute a layer of broken stone for the sub-pavement, and proceed as before.

For a gravel road proceed as with the last, using gravel instead of stone.

ROAD COVERINGS.

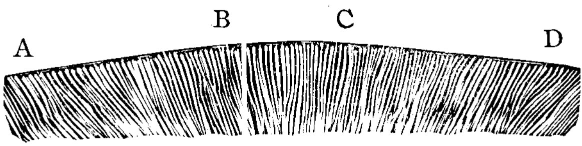
The use of a road covering is two-fold. As earth readily absorbs water and when thus softened absorbs work, and expands by freezing, the road covering is needed for a roof. And, as even dry and compact earth yields and breaks under pressure (especially if unconfined), thus consuming work, the road covering is needed for a floor both for diminishing the intensity of pressure (by distributing it over larger area), caused by the wheels and hoofs, and for preventing any upward bulging of the earth. Hence the qualities to be sought in a road covering are tightness for shedding water, strength and thickness for distributing pressure, and toughness for wear. The fact that the Telford road in table 4 shows better results than the Macadam is due in the writer's opinion solely to the better distribution of pressure afforded by the sub-pavement. Being somewhat cheaper than the Macadam on account of the sub-pavement too, it is in the writer's opinion, the preferable road, especially where the drainage is at all defective. The unfavorable showing made (table 4) by the gravel road in comparison with either of the broken stone roads is due to the fact that the rounded gravel will not unite and become a solid sheet. Thus it does not seem to turn water or distribute pressure so well as the other two. Moreover the rounded pebbles easily turn under the wheel, thus grinding each other and consuming work. Broken stone, if applied in layers of greater depth than 3 or 4 inches, seldom gets compact and solid. The angular pieces continually turn under the wheels or roller, and, by grinding off the angles, become an unstable mass. Stone for a road covering should be broken so as to pass in any direction through a ring not larger than 2½ inches in diameter. It should be kept free from rounded (river) sand, and from clay or any earth that becomes slippery when wet. But a positive gain comes from mixing with it a small quantity of sharp clean sand or small clean chips of the stone itself. Care must be taken however to add these in quantities too small to fill the voids between the stones. Such a filling helps to bind the stones into a solid mass. A greater thickness of broken stone than 12 inches is seldom needed. As little as 5 or 6 may suffice for moderate traffic. But stones as great as 4 inches in any direction should not under any circumstances be spread upon the road, and for still greater reasons should not larger ones. They never, either under the wheels or under the roller, consolidate into a homogeneous covering.

A DANGEROUS PRACTICE.

To let a bridge company furnish its own plans and specifications without the approval of a competent engineer, and to accept the finished bridge without even knowing that it has been erected in accordance with these plans and specifications, is a criminal act. A bridge expert alone can decide whether the plans are safe or whether they have been complied with. The bridge company can save many dollars by making the bridge a little weak. No man should ever be allowed to decide how much risk to other people's lives should be taken to save a dollar to himself.

THE CROSS SECTION.

The road should not have a curved cross section. That would



make the road too flat to shed water well at the top, and too steep at the sides, for vehicles to travel without a tendency to slide. A better form of section is that shown in the figure. It should consist of two straight lines AB and CD, connected at the crown by a short curve BC. The straight lines should have a rise of about 1 in 24, and this should be slightly increased for an earth road.

MAINTENANCE.

That "a stitch in time saves nine" is doubly true of roads. Every rut, hole, or projection of any kind, takes some of the horse's work and turns it against the road itself. A certain amount of mending done every day is many times as effective as the same amount done once a year. It is far cheaper to maintain a road in good condition than in bad.

TIRES AND SPRINGS.

The habit of cutting the road with narrow tires should be stopped by imposing a heavy tax on vehicles with less tire width than 1½ inches for each horse. This would require tire widths of 1½, 3, and 6 inches respectively for vehicles drawn by 1, 2, and 4 horses. Such tires would give lighter draught and do far less damage to the road.

For vehicles with springs the above tire widths might be reduced one-third.

TABLES.

Rise per 100.	Table 8. The figures show how many times as heavy a load a horse can draw, without extra effort, as on a level earth road.						Table 9. The figures show how many times as heavy a load a horse can draw, without extra effort, as on a level road of its kind.					
	0	3	6	9	12	15	0	3	6	9	12	15
Earth Road	1.00	.75	.60	.50	.43	.37	1.00	.75	.60	.50	.43	.37
Gravel Road	1.39	.95	.72	.58	.49	.42	1.00	.68	.52	.42	.35	.30
MacAdam Road	3.13	1.52	1.00	.75	.60	.51	1.00	.50	.32	.24	.19	.16
Telford Road	4.35	1.75	1.11	.81	.64	.53	1.00	.40	.26	.19	.15	.12
Plank Road	4.76	1.85	1.14	.83	.65	.53	1.00	.38	.23	.17	.13	.11
Stone Trackway	16.67	2.50	1.37	.93	.71	.58	1.00	.17	.09	.06	.04	.04